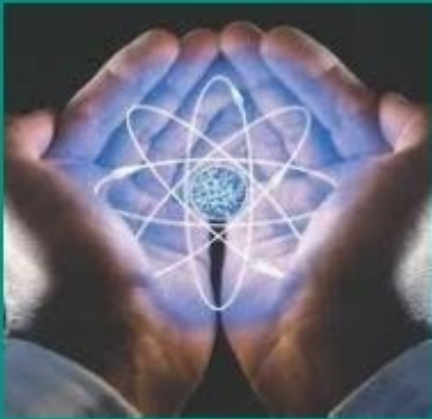

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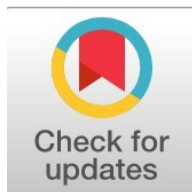
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Econometric Analysis of the Relationship Between Crop Yields Under Agricultural Risk Diversification

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Abstract

General Background: Agricultural diversification is a vital strategy for reducing systemic risks and stabilizing farm income under climate variability. Specific Background: In Uzbekistan, particularly in the Namangan region, limited empirical evidence exists on how wheat and cotton yields interact within the framework of risk diversification. Knowledge Gap: Despite global studies on crop diversification, the causal and econometric relationships between major crops under local environmental conditions remain underexplored. Aims: This study examines the temporal and econometric interdependence between wheat and cotton yields from 1990 to 2024 using correlation analysis, Granger causality tests, and Vector Autoregression (VAR) modeling. Results: Findings reveal that while most districts exhibit weak or negative correlations conducive to diversification, the Chust district shows a strong positive yield relationship due to similar agronomic conditions. Granger causality indicates that in Kosonsoy and Norin, wheat yield significantly influences cotton yield, whereas in Turaqo'rg'on the reverse holds true. Novelty: The study introduces a district-level econometric assessment of inter-crop dynamics, highlighting asymmetric causal patterns shaped by soil and water resource variations. Implications: Results suggest that optimizing crop rotation and water distribution can mitigate covariate risks and stabilize farmers' income, offering evidence-based guidance for regional agricultural policy in Uzbekistan.

Highlight :

- ♦ The study examines the econometric relationship between wheat and cotton yields under agricultural risk diversification in Namangan region.
- ♦ Results show varied correlations and causal directions, influenced by soil and water resource conditions.
- ♦ Findings support policies to enhance crop rotation, resource management, and income stability for farmers.

Keywords : Agricultural Risks, Diversification, Wheat, Cotton, Yield

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Introduction

In global agricultural practice, crop rotation is recognized as a strategic approach to managing production risks at the farm level. Crop rotation in agriculture refers to the systematic alternation of different crops on the same field from year to year. The primary objective of this approach is to maintain soil fertility and to provide a natural mechanism for controlling various pests and diseases. Moreover, crop rotation serves an equally important function — it contributes to the diversification of production risks, thereby enhancing the stability and sustainability of agricultural output.

According to the Food and Agriculture Organization of the United Nations (FAO), crop diversification under conditions of climate change can reduce yield variability by up to 30 percent [1]. Within farming systems, diversification based on the non-proportional (inverse) correlation between the yields of rotational crops allows for the mitigation of production (yield) risks and contributes to the stabilization of farm incomes.

Achieving a strong positive correlation between crop yields can lead to higher productivity for both crop types and an overall increase in farm income. However, such a correlation also exposes these crops to the same category of production risks. For instance, natural factors such as drought may adversely affect both crops simultaneously. As a result, yields and farm revenues decline, and the farming system becomes vulnerable to correlated risks — thereby reducing the effectiveness of diversification.

The smaller or more negative the correlation between crop yields, the greater the opportunity to diversify them away from exposure to the same category of production risks. This, in turn, prevents sharp year-to-year fluctuations in farm income. In other words, the lower (or more inverse) the correlation coefficient between agricultural crop yields, the higher the potential for effective diversification against common risk factors.

Analyses of risk assessment at the farm level demonstrate that the nature of risks within individual farms fundamentally differs from those observed at the sectoral or industry level. The risk portfolio of a single farm is largely determined by internal factors such as soil quality, agronomic practices, management efficiency, and labor productivity. In contrast, sectoral risks—such as drought, water scarcity, declining market prices, or changes in government policy—affect the entire agricultural industry. Therefore, farm-level risk analysis should be based on local characteristics and must be distinguished from macro-level or sectoral risk assessments.

By selecting crops with appropriate yield and price correlations and by designing rational crop rotation strategies, farmers can diversify their production portfolios, thereby stabilizing and increasing their income levels over time.

Methods

Research confirms that farmers can increase their incomes by strategically utilizing certain correlations in their risk management practices. In general, farm households can stabilize their income levels by exploiting the inverse correlation between prices and yields, as well as by diversifying production based on non-proportional correlations between the yields and prices of different agricultural crops [2].

The inverse correlation between prices and yields is an economically justified phenomenon. In years of high productivity, the increased supply of agricultural products in the market tends to drive prices downward. Conversely, during years of low yields, the reduced supply contributes to upward pressure on agricultural product prices [3].

As a result, the inverse (negative) correlation between yield and price serves as a “natural economic buffer” for farms, allowing income stability even in years of low productivity, when higher market prices compensate for reduced output. This mechanism is recognized in global practice as one of the most effective methods of risk mitigation and represents a core principle of agricultural diversification.

Therefore, dynamic analysis of yield fluctuations, particularly the identification of their interrelationships, plays a crucial role in ensuring agricultural stability. In the context of Uzbekistan, regional dynamics of crop yields have been insufficiently studied from an economic cause-and-effect perspective. For this purpose, the relationship between the yields of winter wheat and raw cotton was evaluated using econometric models based on data from the districts of the Namangan region.

Results

A strong (high) correlation between the yields of agricultural crops indicates that losses from one crop type are highly associated with losses from another. Yield reductions often reflect a high degree of correlation across large areas. For example, natural disasters such as droughts, extreme heat, or floods can simultaneously affect the yields of multiple crops over vast territories, leading to significant declines or total losses in farm output. This situation reflects the systemic nature of agricultural risks.

Thus, if a risk simultaneously affects the yields of multiple farms within a specific region and recurs regularly over time, it is classified as a systemic risk (Figure 1) [4].

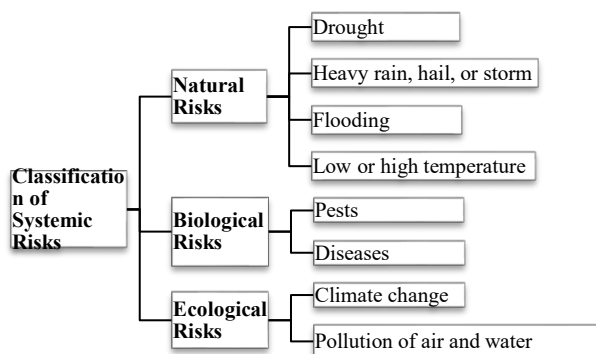


Figure 1. Classification of Systemic Risks Affecting Agricultural Crop Yields [5]

Systemic risks may trigger the occurrence of other types of risks, such as production or price risks. For instance, the drought that occurred in Russia in 2010 caused severe damage to grain crops cultivated over vast areas. Since Russia is one of the world's largest grain exporters, this event led to a sharp increase in global grain prices. Consequently, it contributed to the aggravation of food insecurity in many countries across Africa and Asia [6].

A high (strong) degree of correlation between the yields of agricultural crops cultivated by farms indicates their exposure to systemic risks.

Statistical analysis indicates that production (yield) risk affects agricultural crops grown within a given region in a relatively uniform manner, leading to variations in farm-level productivity and resulting in a weak correlation between crop yields. However, price risk is linked to market conditions, and since it tends to influence the prices of most agricultural products simultaneously, these prices often exhibit a high degree of correlation.

The correlation analysis of cotton and wheat yields produced by farms in the Namangan region during the period 1990–2024 revealed that the yield indicators of these crops are linked at varying degrees (see Figure 2).

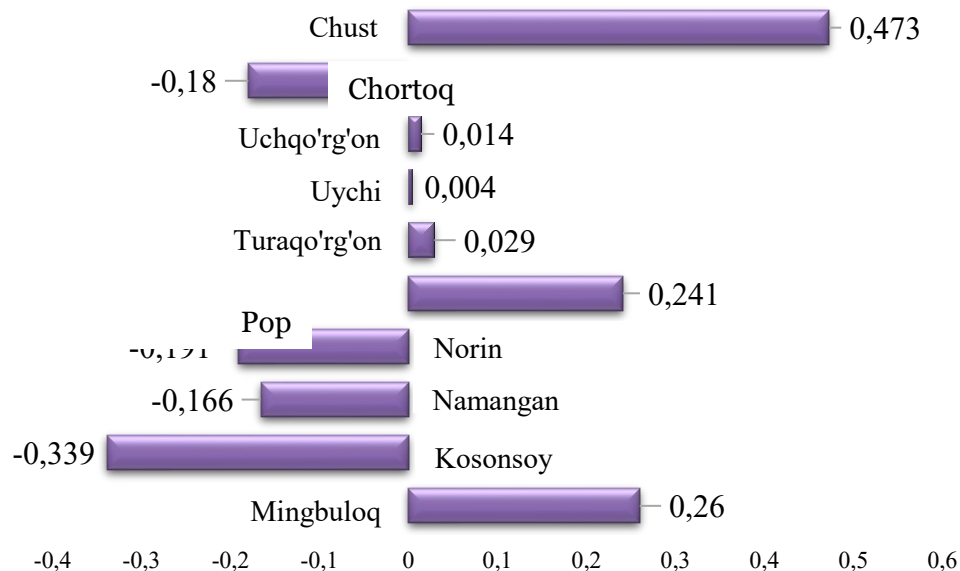


Figure 2. Correlation coefficients of winter wheat and cotton yield indicators produced by farms in the Namangan region during 1990–2024 [7]

The degree of relationship between these two variables (wheat and cotton yields) was determined using the following formula [8]:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

According to the analysis, in most districts the correlation coefficient was less than 0.3, indicating a weak relationship. In particular, the Mingbuloq ($r \approx 0.26$) and Pop ($r \approx 0.24$) districts showed a weak positive correlation, reflecting that the production of these two crops in these areas tends to vary in a slightly similar manner.

In the districts of Kosonsoy ($r \approx -0.34$), Namangan ($r \approx -0.17$), Norin ($r \approx -0.19$), and Chartak ($r \approx -0.18$), a negative correlation was observed. This situation likely results from disparities in water availability or inconsistencies in the allocation of cultivated land between the two crops.

In the Turaqo'rg'on, Uchqo'rg'on, and Uychi districts, the correlation coefficients were close to zero ($r \approx 0.029$; $r \approx 0.014$; $r \approx 0.004$), indicating that the yields of these crops have almost no mutual influence.

In contrast, the Chust district ($r \approx 0.47$) exhibited a relatively strong positive correlation, suggesting that in years when winter wheat yields were high, cotton yields were also elevated. This pattern reflects the efficient and simultaneous use of similar agronomic resources for both crops in this area.

Discussion

Correlation refers to the degree of interdependence between two variables (for example, the yields of winter wheat and cotton). From an econometric perspective, correlation does not indicate causation but merely reflects a statistical association between variables. This means that even if a correlation exists between wheat and cotton yields, it does not necessarily imply that wheat yield influences cotton yield. The reason is that both crops may be simultaneously affected by common external factors such as climatic conditions or water distribution.

Therefore, in economic and statistical analysis, it is important to identify whether a causal relationship exists between time series variables. Granger causality is a statistical test that determines whether one time series variable can help predict another over time [9].

1. If the past values of one variable, X_t (for example, wheat yield), improve the prediction of the future values of another variable, Y_t (cotton yield), then $X \rightarrow Y$ is said to exhibit a temporary causal influence [10].

To identify such a relationship, two time series — X_t and Y_t — are considered. In the first step, Y_t is predicted solely based on its own lagged (previous) values:

$$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + \varepsilon_t$$

In the second step, the previous values of X_t are added, and the model is reformulated as follows:

$$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + b_1 X_{t-1} + b_2 X_{t-2} + \mu_t$$

If the coefficients b_1 and b_2 are statistically significant, then $X \rightarrow Y$ is said to exhibit a causal relationship. Conversely, if these coefficients are statistically insignificant, it indicates that X has no causal effect on Y , and the behavior of Y can be explained solely by its own past values [11].

In this case, both time series must be stationary, meaning that their mean and variance remain constant over time. The difference in explanatory power is evaluated using the F-test. If the p -value of the F-test is less than 0.05, the causal relationship is considered statistically significant; if $p > 0.05$, no causal effect is present. For example, if in the direction “Wheat $\rightarrow$ Cotton” the p -value equals 0.03, this indicates that variations in wheat yield help explain the subsequent year’s cotton yield [12].

Granger causality does not test for a direct relationship but rather examines the temporal association between time series variables. This method is one of the most important statistical tools used in economic, climatic, agricultural, and financial analyses, as it helps to identify which variable is leading and which is lagging in the dynamic relationship (Table 1) [13].

In the analysis, the interaction between the two-time series – wheat (W_t) and cotton (C_t) – for each district was statistically evaluated using the following equation:

$$W_t = a_0 + \sum_{i=1}^p a_i W_{t-i} + \sum_{i=1}^p b_i C_{t-i} + \varepsilon_t$$

where:

W_t – wheat yield in the current year.

W_{t-i} – wheat yield in previous years.

C_{t-i} – cotton yield in previous years;
 a_0 – constant term (baseline yield level);

a_i, b_i – regression coefficients (magnitude of the effects of wheat and cotton, respectively);

ε_t – random error term (unexplained factors such as climatic conditions or agricultural policy influences);

p – lag order (reflecting the influence of past periods).

Table 1. Granger causality relationship between the yield indicators of winter wheat and cotton crops

Districts	Wheat Cotton $\rightarrow$	Cotton Wheat $\rightarrow$	Interpretation
Mingbuloq	No	No	Both crops act independently and are mainly influenced by common external factors such as climate and water availability.
Kosonsoy	Yes	No	Changes in wheat yield affect the following year’s cotton yield.
Namangan	No	No	No causal relationship was identified.
Norin	Yes	No	Wheat yield influences cotton yield, possibly due to the distribution of irrigation water or mineral fertilizers.
Pop	No	No	No causal direction detected.
Turaqo’rg’on	No	Yes	Reverse causality observed: changes in cotton yield affect the following year’s wheat yield.
Uychi	No	No	No significant relationship observed.
Uchqo’rg’on	No	No	Both crops behave independently.
Chartak	No	No	No active causal relationship found.
Chust	No	No	A positive correlation exists, but the causal effect is statistically insignificant.

In the districts of Kosonsoy and Norin, winter wheat yield was found to have a statistically significant effect on the following year’s cotton yield ($p < 0.05$). This relationship likely reflects the influence of soil nitrogen balance or water distribution carried over through the agrocycle [14].

In contrast, in the Turaqo’rg’on district, the opposite effect was observed—changes in cotton yield influenced the subsequent year’s wheat yield. This finding suggests that cotton cultivation may contribute to a decline in soil fertility.

In the remaining districts of the region, no causal relationship between the two crops was identified. The results indicate that variations in wheat and cotton yields are primarily driven by external factors such as climatic conditions, irrigation availability, and agronomic practices [15].

Conclusion

The econometric analysis of the relationship between wheat and cotton yields in the Namangan region from 1990 to 2024 shows that the agricultural production in Uzbekistan is primarily determined by systemic factors, such as climatic variation, water resources availability, and soil characteristics. The findings demonstrate that while the majority of regions are characterized by either weak or negative wheat-cotton yields correlation, which presents effective diversification window, the Chust district is correlated, because of the similarity of agronomical conditions. Moreover, the Granger causality tests show asymmetric casual relationship as wheat yield significantly affected cotton yield, in Kosonsoy and Norin, while in Turaqo’rg’on, the result was reverse. This implies that soil and water relationship is different for the majority of studied regions. The results suggest that regional policymakers should build a capacity of optimization of crop rotation patterns, water resource distribution, and

production structure diversification to eliminate covariate risks and stabilize farmers' income. The study proves that applying econometrical tools, such as VAR models and causality testing, to an agricultural risk provide a basis for evidence-based approaches. In the future, this study will be expanded to dynamically estimate the price-yield relationships and will simulate multi-crop portfolios including climate change adaptation factors. The suggested diversification tools and strategies will serve as a basis for a novel definition of agro-economic rationalization in Uzbekistan.

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